Aerosol and Carbon Monoxide characteristics over Arabian Sea during crop residue burning period in the Indo-Gangetic Plains using multi-satellite remote sensing datasets

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INTRODUCTION

The Indo-Gangetic Plains (IGPs) are one of the world’s largest and highly agriculturally productive areas encompassing vast areas from India (areas in Pakistan and parts of Punjab and Haryana in India) and the Gangetic Plains (Uttar Pradesh (UP), Bihar, and West Bengal in India, Nepal and Bangladesh). IGPs accounts for 21% of the land area of the Indian subcontinent and holds nearly 40% of the total population. Nearly 12 million hectares are used for rice-wheat crop rotation in IGP region. Harvesting of these crops with combine harvesters is very popular among the farmers of Punjab, Haryana and Western Uttar Pradesh.

Each year, during the months of October and November, agricultural crop residues burnt in the Indo-Gangetic Plains (IGPs) has a significant impact on greenhouse gas emissions and aerosol loadings over the region. Mostly, crop residues after harvesting get burnt in these areas because of the high labour wages and anxiety of the farmers to get the crops produce collected and marketed as early as possible.

OBJECTIVES

To analyze the aerosol optical depth and carbon monoxide variations across the IGPs during the intense crop residue burning season.

To study the impact of agriculture crop residue burning on aerosol and carbon monoxide (CO) characteristics over Arabian Sea.

DATASETS AND METHODOLOGY

We have used multi-satellite data from Terra-MODIS, AURA-OMI, Indian remote sensing satellite (IRS)-P4 ocean color monitor (OCM) and measurements of pollution in the troposphere instrument (MOPITT) as well as a back-trajectory model to retrieve aerosol loadings and carbon monoxide (CO) pollution over Arabian Sea, caused due to anthropogenic activities over the Indo-Gangetic Plains (IGPs).

RESULTS AND DISCUSSION

Figure – 1 (a – d)
IRS – P4 OCM & Terra – MODIS False Color Composites

We have characterized the impact of extensive anthropogenic activities associated with major Indian festival known as “Diwali” celebrated on 09th November, 2007 as well as with agriculture crop residue burning on aerosol properties over the Arabian Sea using information from multiple satellites. Figure – 1 (a – d) shows IRS – P4 OCM (a) and Terra – MODIS (b) false color composites (FCC) on the festive day of 09th November, 2007 and after the festival on 13th & 19th November, 2007 (Fig. 1(c) & (d)). Intense smoke plumes emanating from agricultural crop residue burning in the IGP region and hazy atmospheric conditions due to fires over India are clearly visible in Fig. 1(a-d). The hazy atmosphere prevailing over the Arabian Sea can also be seen in OCM and MODIS false color composites.

Figure – 2 (a – c)
MODIS Active fire locations over Indian Region

Figure – 2 (a – c) shows the composite of MODIS active fire locations over Indian subcontinent during 1–10, 11–20 and 21–30 November 2007. It is clear from the Figure – 2 that higher incidence of fires occurred over the IGP region, mainly in the Punjab and Haryana state followed by Uttar Pradesh, Madhya Pradesh and Maharashtra. These fires are mainly attributed to agricultural crop residues burning associated with rice-wheat crop rotation system over the IGP region.

Figure – 3 (a – c)
Terra – MODIS AOD550 variations over Indian Region

Variation in Terra-MODIS derived AOD at 550nm (AOD550) over peninsular India during 1–10, 11–20 and 21–30 November 2007, is shown in Figure – 3 (a-c). The averaged AOD for 1–10 and 11–20 November 2007 shows persistence of high AOD over near-coastal region of the Arabian Sea, whereas an overall decrease in the AOD550 from near coast to far away the coast is evident from the Fig. 3(a) and (b). The spatial spread of AOD550 is more in the coastal regions than in the far coastal regions. This high aerosol loading above the Arabian Sea is mainly attributed to the long-range transport of continental anthropogenic aerosols due to agriculture crop residue burning in the IGP and fireworks associated with the festive activities of Diwali.

Figure – 4

Figure – 4 shows the longitude wise averaged variations in Terra-MODIS derived AOD at 550nm covering 8°-20°N latitude and 68°-72°E longitude over the Arabian Sea during and after the Diwali period. It is clear from the Fig. 4 that Arabian Sea was influenced by anthropogenic aerosol loading during the Diwali period. Nearly a ~30% increase in AOD550 values was observed during the Diwali period compared to the post-Diwali period, suggesting an additional load of aerosols over the region mainly transported from the landmass to the oceanic region.

Figure – 5 (a – c)
MOPITT CO variations over Arabian Sea

The AI is a qualitative measure of the presence of UV-absorbing aerosols such as mineral dust and smoke. The composite of OMI derived AI values during 1–10, 11–20 and 21–30 November 2007, respectively, are shown in Fig. 5 (a–c). High AI values were observed during the festive period compared to the post-festive period over the Arabian Sea, suggesting a higher concentration of absorbing aerosols species emitted due to crop residue burning and fireworks. AI values over the Arabian Sea varied from a minimum of 0.8 to a maximum of 1.5 during the festive period, while during the post-festive period the values remained in the range 0.8–1.2.

To characterize the dispersion of aerosols in the study region, the wind data at 850 hPa from NCEP were analyzed. Figure – 7 (a-c) shows the averaged wind speed and direction at 850 hPa during 1–10, 11–20 and 21–30 November 2007. It is clear from Fig. 7b-c that, the wind direction during 11–20 and 21–30 November 2007 was persistent westerly flow with high intensities in the northern part of India (Ganges valley) and low in the middle part. The prevailing high southwesterly winds (8–10 m/s wind speed) at 850 hPa contributed to the dispersion of the tropospheric aerosols over the Arabian Sea.

CONCLUSIONS

Crop residue burning and fireworks ignition during the Diwali festivities significantly affects atmospheric composition around the Indian subcontinent. In this study we have shown that the changes in atmospheric composition are even detectible by satellite remote sensors. Results of the multi-satellite data analysis showed that:

- A ~30% increase in AOD550 observed over the Arabian Sea during Diwali period, mainly due to long-range transport of aerosols emitted due to crop residue burning in the IGP region and fireworks;
- A relatively high AI and high values of CO observed above the Arabian Sea were mainly attributed to anthropogenic sources in the Indo-Gangetic Plains of India.

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